Summer 2017 REU Report

Eliza Gazda

University of Chicago

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Abstract

Large area picosecond detectors can be developed and applied to detect photons in fields like science and medicine, allowing improvement in the speed and quality of photon detection. The development of the detectors includes the building a vacuum environment for assembly of the detector, use of the most optimal material in each part of the detector, and the ability to very precisely test the detector. This report describes quality control (QC) test on the base part of the detector and quantum efficiency (QE) setup adjustments for testing the effectiveness of the photocathode in the detector. The results provide the data on ceramic bases from multiple vendors. Vendor ICE has the most precise and pure ceramic. Also this report describes techniques for decreasing noise in the development process like eliminating ground loops and differential signaling.

1 Introduction

LAPPDs are large area picosecond detectors developed to measure particles at picosecond timing. Applications of the LAPPD include accelerator instrumentation, neutrino detection, and PET scans. By developing the LAPPDs particle detection technology can improve in medical and scientific fields.

Currently the PSEC group works on developing LAPPDs. Some of the main current tasks are developing a vacuum system for creating the cathode and testing the quantum efficiency of the LAPPDs. Another task is determining the best materials and process for the development of the detectors.

This paper describes two projects (QC and QE) that help in the development of the instruments.

2 QC (Quality Control)

QC is a project that tests the quality control used to evaluate the properties of LAPPD ceramic bases shown in Figure 1 by making various precise measurements and tests. Tests and measurements include comparisons of dimensions, density, and flatness of the ceramics from three different ceramic vendors (Coorstek, Aremco, ICE) and one brazing base vendor (Sigma). The measurements are used to determine which bases meet the specifications in assembly into the LAPPD and how to compensate for any inaccuracy in the bases that will be used. Also a database of the base measurements is at ceramicbases.uchicago.edu [1].

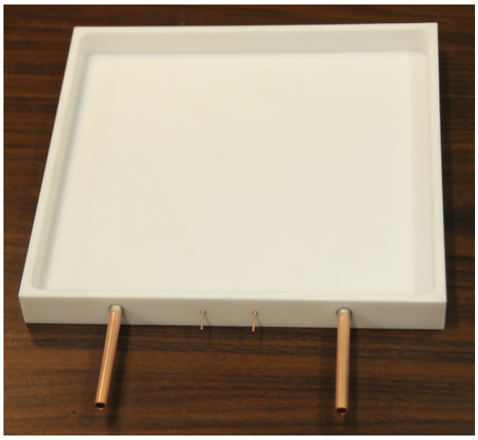


Figure 1: Ceramic base measured and characterized for quality control (for a ceramic base spec sheet with dimensions and tolerances see Appendix A)[2].

2.1 Procedures

Each test and measurement method performed on the ceramic bases is described in the following sections. The LAPPD is a sealed vacuum package, so the precision of the ceramic sealing surface should be to 0.001 inch to prevent leaks. Also the depth of the base should be precise and parallel to the sealing surface, so that the components put inside the base are at the proper height, to seal the detector and not break the glass placed on top. In order to keep the measurements accurate, multiple methods described in the following sections were used to determine properties of the bases and the results were compared to determine to consistency of the testing and the standard deviation between each ceramic base.

2.1.1 Dimension Measurements

Five measurement were performed on each ceramic base using depth and height gauges, a micrometer and a granite flat. These measurements include:

- Height: measured using a micrometer from the bottom surface of the plate to the top surface of the side wall. There were 8 measurements total, one at each corner and in the middle of each side.
- Depth: measured by placing a calibrated, flat, metal plate with 25 drilled holes on top of the ceramic. Then a depth micrometer was placed through each hole to the bottom surface inside the base.
- Flatness: measured by placing the same calibrated, flat metal plate on top of the ceramic. Then using only 8 holes drilled on the outside of the metal plate, a depth micrometer was put on the top of the metal plate to the top surface of the side wall at each point.
- Mass: Each base was weighed on a scale at about ± 1g uncertainty.
- Width and Length: measured by using a large caliper. The caliper is placed to measure dis-

tance from one inner side of the wall to the other inner side of the wall at both the width and length.

Each base required 8 height, 25 depth and 8 flatness measurements. These points were plotted to show maps of each base as shown in detail in the on-line database [1]. Further details of measurement procedure are described in Appendix B.

2.1.2 Density Calculation and Measurement for Aremco Bases

The variation in material properties and bases was evaluated by calculating the density of each unbrazed base from Aremco.

Each base was weighed to determine the mass; however because some bases were brazed their mass varied, therefore only unbrazed bases were used for density calculation. Precise measurements of height and depth of each plate were averaged and used in the volume calculations. The other dimensions (inside and outside width of the bases) were taken from the specification sheet as shown in Figure 9 in Appendix A. The volume of the two holes is determined from the specification sheet and subtracted from the entire calculation. Equation 2 and Equation 3 show the density calculation.

$$V = w_1 l_1 h_{avg} - w_2 l_2 d_{avg} - (hole_1 + hole_2) \quad (1)$$

$$D = \frac{m}{V} \quad (2)$$

where D is density in g/cm^3, V is volume in cm^3, m is mass in g, w_1 is the width measured from the outside and w_2 is width measured from the inside, l_1 is length of the outside of the base and l_2 is length of the inside of the base in inches, h_{avg} is the average height measured for each base between 8 points, and d_{avg} is the average depth measured for each base between 8 points.

2.1.3 Microscope Images

A microscope image was taken of a sample ceramic base to determine the grain average size and surface flatness. This test is a trial measurement of the ceramic using a prospective 3D Laser scanning microscope (VK-X100K/X200K) from Keyence . Figure 2 shows the resulting images. The average grain size is about 10 micrometers.

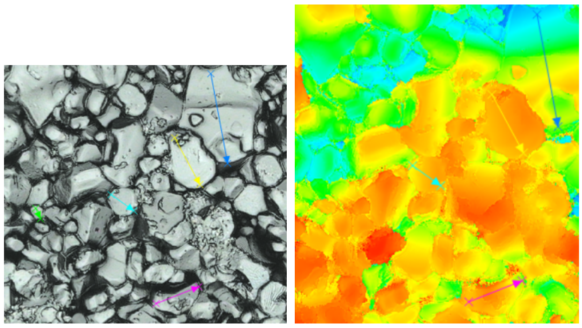
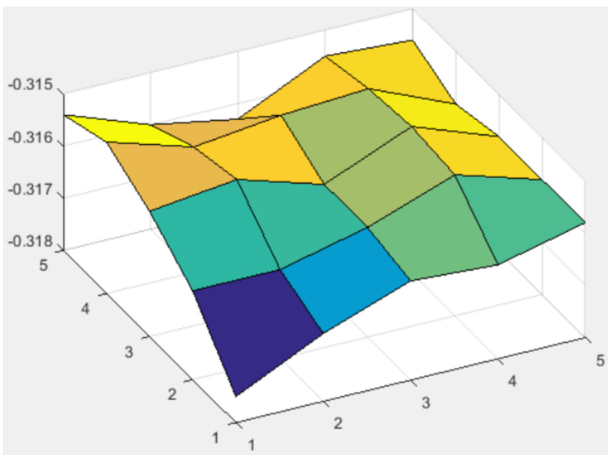


Figure 2: Images of a sample ceramic base from Aremco. The laser-optical image on the left shows the actual grains of the ceramic on the micro meter scale. The image on the right shows the laser 3D image of depths in the sample (the color represents the altitude at the image point).

2.2 Results

The plots of flatness for measurements of each plate from all three vendors are on the on-line database [1]. Figure 3 shows the general plots generated for one base from Aremco.

The scale of the z-axis is much smaller than on the x and y-axis, so any inconsistencies on the plates are greatly exaggerated. The colors of the plots represent the slope of the point and each intersection of a square surface is a measured point.



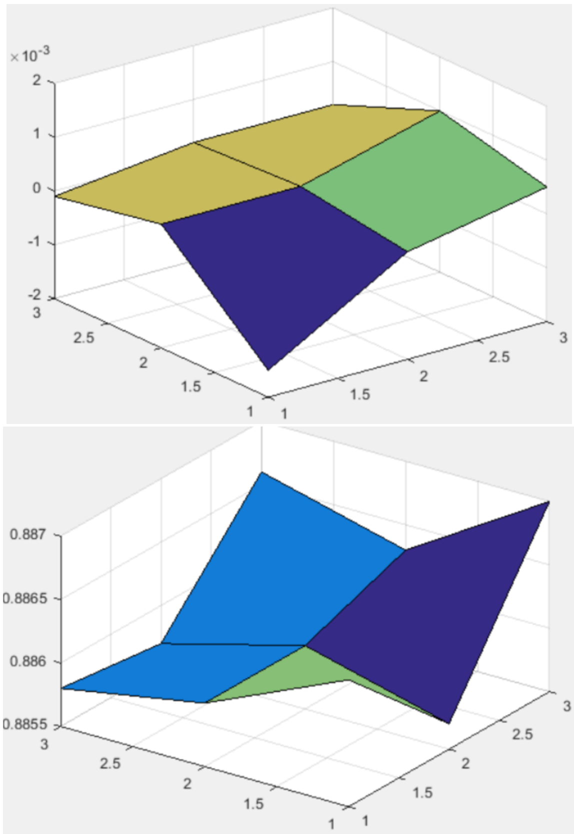


Figure 3: Results of inner depth, sealing surface depth, and height of the first ceramic base measured from Aremco.

The results for density values from unbrazed Aremco bases are shown in Table 1.

Aremco Density Values	
Base Number	Density ±0.7 % (g/cm^3)
1	3.60
2	3.62
3	3.61
4	3.65
5	3.66
6	3.61
7	3.66
8	3.61
9	3.62

Table 1: Density Results for Aremco. The standard deviation is 0.022g/cm^3 or 0.6% of the volume.

The standard deviation between the tiles (0.6%) is similar to the percent error of the measurements (0.7%).

The volume and mass of brazed bases are shown in Table 2

Volume and Mass for Brazed Bases			
Vendor	Base Number	Volume (cm^3)	Mass (g)
ICE	1	322.7	1395
ICE	2	320.4	1383
ICE	3	323.2	1395
ICE	4	321.8	1393
ICE	5	317.9	1373
Coorstek	1	331.1	1362
Aremco	2	320.1	1265
Aremco	3	319.1	1300
Aremco	4	319.8	1298

Table 2: Volume and Mass measurement from Aremco, Coorstek, ICE, brazed by Sigma.

The raw data shows a large variance in mass due to the brazing of these bases, for this reason the density was not determined.

2.3 Calculation of Uncertainty on Density

The percent uncertainty on the density took into account possible measurement imprecision in each dimension used for volume calculation in Equation 1. While measurements of depth and height of each plate had an error of only about ±0.2 mils, the values for width obtained from the specification sheet had an error of ±0.02 inch. From the specification sheet, the width was determined to be: $w_1 = w_2 + 0.4$ with negligible error (using the variable convention from Equation 1. Plugging this into Equation 1 and rearranging, the resulting 3 is:

$$V = {w_1}^2(h_{avg} - d_{avg}) + 0.8w_1h_{avg} + 0.4^2h_{avg} \tag{3}$$

The last term has negligible error, and the error of w_1, h_{avg}, and d_{avg} is known. Using the standard formula for multiplication, addition, and squaring of values with error, the total error in volume was found to be ± 0.13 in^3, or 0.68%. Factoring in the mass uncertainty of ± 1g from the scale, the error in density was found to be 0.025 g/cm^3 or 0.69%. The calculated standard deviation in density of the bases from Aremco, was 0.022 g/cm^3 or 0.62%, which is close to the predicted error, supporting the validity of our calculations.

2.4 Conclusion and Vendor comparison

A summary of data analysis and comparison of brazed ceramic bases is shown in Table 5. This section describes the main differences and features of bases from each vendor.

1. The unbrazed Aremco ceramic bases have a very consistent density with a percent difference of about 0.6%, however, each tile tends to have larger differences between its dimensional measurements.

2. The ICE bases at 98% purity have the smallest standard deviation in depth of the bases resulting in the flattest surface, however the sealing surface has a larger standard deviation. All dimensions are within the spec sheet allowances. The ceramic is discolored which may be a result of the purity at 98% of ceramic being exposed to UV light after brazing. Base 3 has a scratch on the sealing surface shown in Figure 4

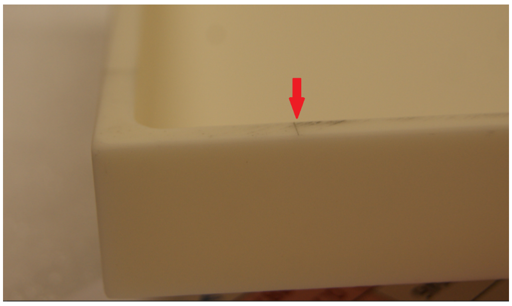


Figure 4: Scratch on ceramic base ICE base 3 sealing surface.

3. The Coorstek base at 96% purity has accurate dimensions and the ceramic looks clean, however, a major issue is a rim on the inside of the base shown in Figure 5. The rim may cause uneven coating during metalization.

Figure 5: Rim on ceramic base Coorstek base 1 inner surface.

4. The Aremco bases at 96% purity have the largest standard deviation between measurements but still within allowances. The ceramic is has gray discolored spots and the surfaces do not feel even. The Aremco bases are accurate compared to the spec sheets, however, they contain the largest inconsistencies in dimensions as compared to other vendors. The purity of Aremco is 96%.

The data analysis of each base showed that the bases vary between some precise and imprecise features between each vendor. The most consistent is ICE with very consistent dimensions and higher purity.

3 QE (Quantum Efficiency)

QE, or quantum efficiency, is a measure of the effectiveness of the photo-cathode, defined as the ratio of the number of electrons emitted to the number of photons hitting the photo-cathode shown in Equation 4.

$$QE = \frac{electrons}{photons} = \frac{i_0/q_{e^-}}{P_{tot}/E_\gamma} \tag{4}$$

where i_0 is the current measured, q_{e^-} is the charge of one electron, P_{tot} is the total power of photons, and E_γ is the energy of one photon.

Being able to measure QE precisely is a critical part of evaluating, testing, and understanding the LAPPD. This section describes the current methods used in Margherita I to determine QE of LAPPDs and new improvements added to the method, also future ideas about improvements and new QE designs.

3.1 Current QE Design

Margherita I is a vacuum chamber and system for cessation and testing of the quantum efficiency of the LAPPD. The current QE setup in the Margherita involves a motor controlled fiber optics cable that moves and flashes light at set wavelengths and at set points of the LAPPD. Throughout this project it is important to have a detailed diagram of the QE setup providing the ability to fix issues with noise and improve the QE system. Figure 10 in Appendix C shows a detailed diagram of the current setup.

Generally there is an LED light source that flashes at 350Hz at the LAPPD. Then the current is measured and passes through multiple circuits to be measured by a Lock-in amplifier and a Kethley picometer. The Lock-in amplifier allows some elimination of noise by being synced at 350Hz with the same function generator as the LED source.

By mapping put and understanding the QE setup some of the following issues were found to complicate the QE measurement:

1. Noise through ground loops
2. Noise through switch mode power supplies.
3. Overcomplicated low pass circuit
4. Long BNC connections between instruments create antenna noise that pick up ambient electromagnetic waves from around the room.
5. Inconsistent power output from the LED box.

3.2 Improvements

This section describes some techniques and improvements to the QE setup to minimize signal noise and optimize the QE measurement.

3.2.1 Implementation of a differential signal

One reason for noise in the QE setup is the antennas created due to long BNC connections throughout the system. Implementing differential connections using Ethernet cables is one technique used to elimination of noise.

A differential signal is obtained from the difference in voltage between two wires, as opposed

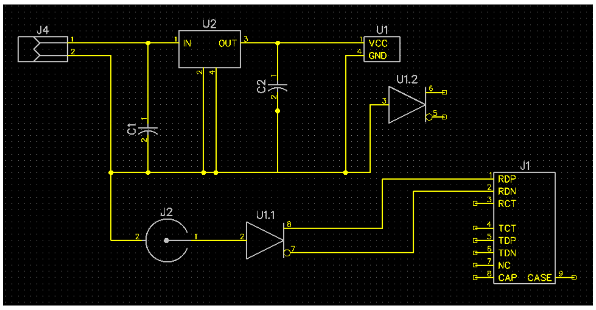


Figure 6: Circuit diagram for a driver that converts signal from TTL to differential. The components are: J1=Ethernet connector for differential output to circuit in Figure 7, J4=power connector, J2=BNC TTL input connector from function generator, U2= voltage regulator to 5V (LM2937ES), C1 = .1μF capacitor, C2 = 10μF capacitor, U1 and U1.1 and U1.2 are the DS9638CM driver chip that converts from TTL to Differential.

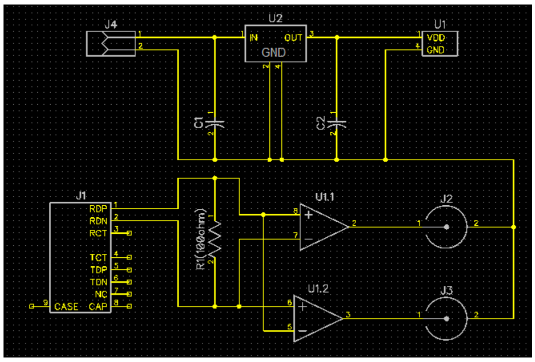


Figure 7: Circuit diagram for a receiver that converts signal from differential to TTL. The components are: J1=Ethernet connector for differential input from circuit in Figure 6, J4=power connector, J2=BNC TTL output connector to LED box (at phase), J3=BNC TTL output connector to LED box (out of phase), U2= voltage regulator to 5V (LM2937ES), C1 = .1μF capacitor, C2 = 10μF capacitor, R1= 100Ω resistor, U1 and U1.1 and U1.2 are the DS9637ACN receiver chip that converts from Differential to TTL.

to the voltage of a wire relative to fixed ground. While one wire has a certain positive current I, the other wire will have the negative current -I, so that the net current through the two wires is always 0, even while a changing signal is being transmitted.

A connection with an Ethernet cable is differential and can be implemented between the function generator and the LED box.

The circuits shown in Figure 6 and 7 allow for conversion of a TTL signal from the function generator to a differential signal and a differential signal back to TTL to enter the LED box. The two circuits are connected by an Ethernet cable.

An advantage of differential signaling is that noise affecting both wires equally does not change the relative voltage, and so the signal is unaffected. In addition, since the net current through the wires is 0, ferrite beads or other noise reducing devices that filter out changing current can be used without interfering with the signal.

3.2.2 Design of Box 2 Circuit

Box 2 as shown in Appendix C, Figure 10 contains an overcomplicated design with too many random components, random grounds connected, and unused BNC outputs. An improvement of the design was implemented to reduce the noise created by the Box, the new circuit is shown in Figure 8.

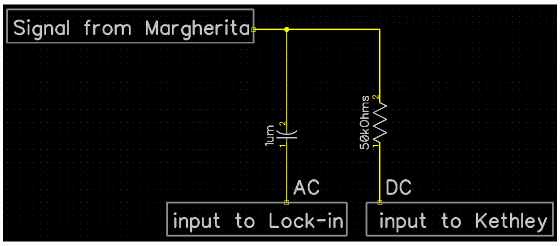


Figure 8: Low pass filter circuit diagram for current and signal coupling to the Lock-in amplifier and Kethley shown in detail Appendix C. Capacitor is at $1\mu F$, Resistor is at 50kΩ

3.3 Results

Currently QE testing is being used for LAPPDS that still are in development with the setup from Appendix C and a few improvements. Box 2 is already implemented in the setup and works well.

The differential signaling technique has not been applied yet, however, the circuits were tested using an oscilloscope and LED box to compare a TTL output from the function generator to the output of the circuit. Results of the tests are shown in Table 3.

Circuit	Peak Voltage	Notes
D1	Bad Circuit (wrong capacitance)	
D2	Good, chip heats slightly	
D3	Good, chip heats slightly	
R1	Bad Circuit (low voltage amplitude)	
R2	$\approx$ 4.04 to 1MΩ	Slight ripples on oscilloscope, but consistent with LED box
R3	$\approx$ 4.16 to 1MΩ	very consistent

Table 3: Data of Differential and TTL Driver (D*) and Receiver (R*) Circuits

4 Conclusion

The current adjustments to the QE setup are in progress of being implemented and are working well individually. When implemented, Box 2 works in the Margherita 1 system. However, there are still problems with the system and some future ideas of techniques to reduce noise and improve the QE setup are:

1. Using linear power supplies instead of switch mode powers supplies
2. Eliminating ground loops and applying a star model for ground connection with a single ground input.
3. Measuring the power output of the LED at the end of the fiber with a diode to consistently calibrate the photon output during measurement.
4. A completely new design of the QE setup with multiple stationary fiber-optics cables instead of a motor controlled fiber.

A Margherita 2 vacuum chamber is in the process of development and with the new noise reduction techniques the QE in Margherita 2 should be much more efficient.

5 Acknowledgements

I would like to thank the PSEC group, Dr. Henry Frisch, and the REU coordinators for the summer research experience and for allowing me to gain the knowledge of experimental physics in both coding, hardware, and many techniques used to work with high energy physics.
I would also like to thank NSF for the grants in this REU.

References

[1] Gazda, Eliza. LAPPD^{TM} Ceramic Bases, University of Chicago, ceramicbases.uchicago.edu/.

[2] 284 Gen II Ceramic Tile Base. richn_ceramic_tile_DSC_6775.jpg from Rich/Henry. Image last updated: February 16, 2017. image-library.uchicago.edu

[3] 302 Ceramic Tile Base Rev C richn_CeramTB111015revC.pdf from Rich Northrop Image last updated: August 03, 2017. image-library.uchicago.edu

6 Appendix

A Specification Sheet

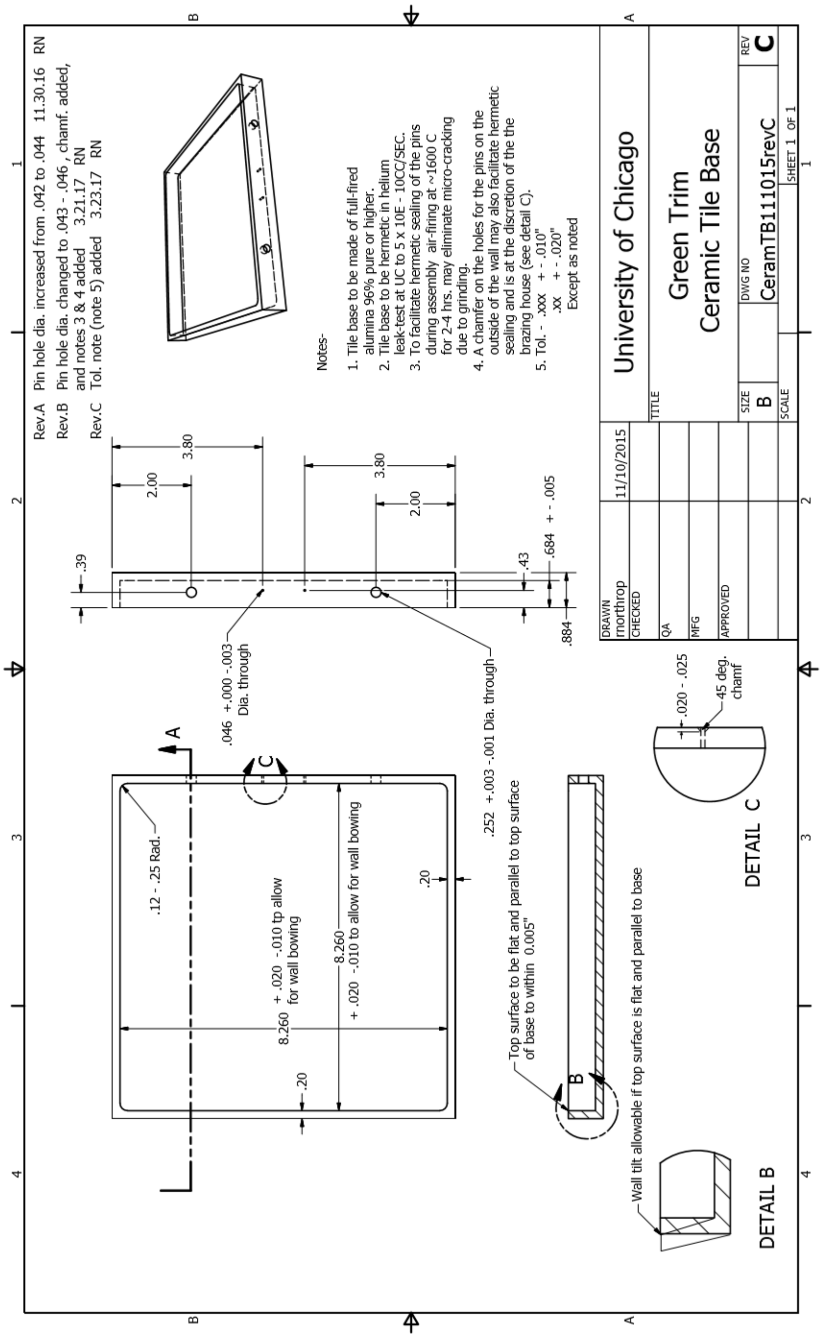


Figure 9: Specification sheet showing all desired dimensions of the ceramic base.[3]

B Deviation form Nominal Dimensions

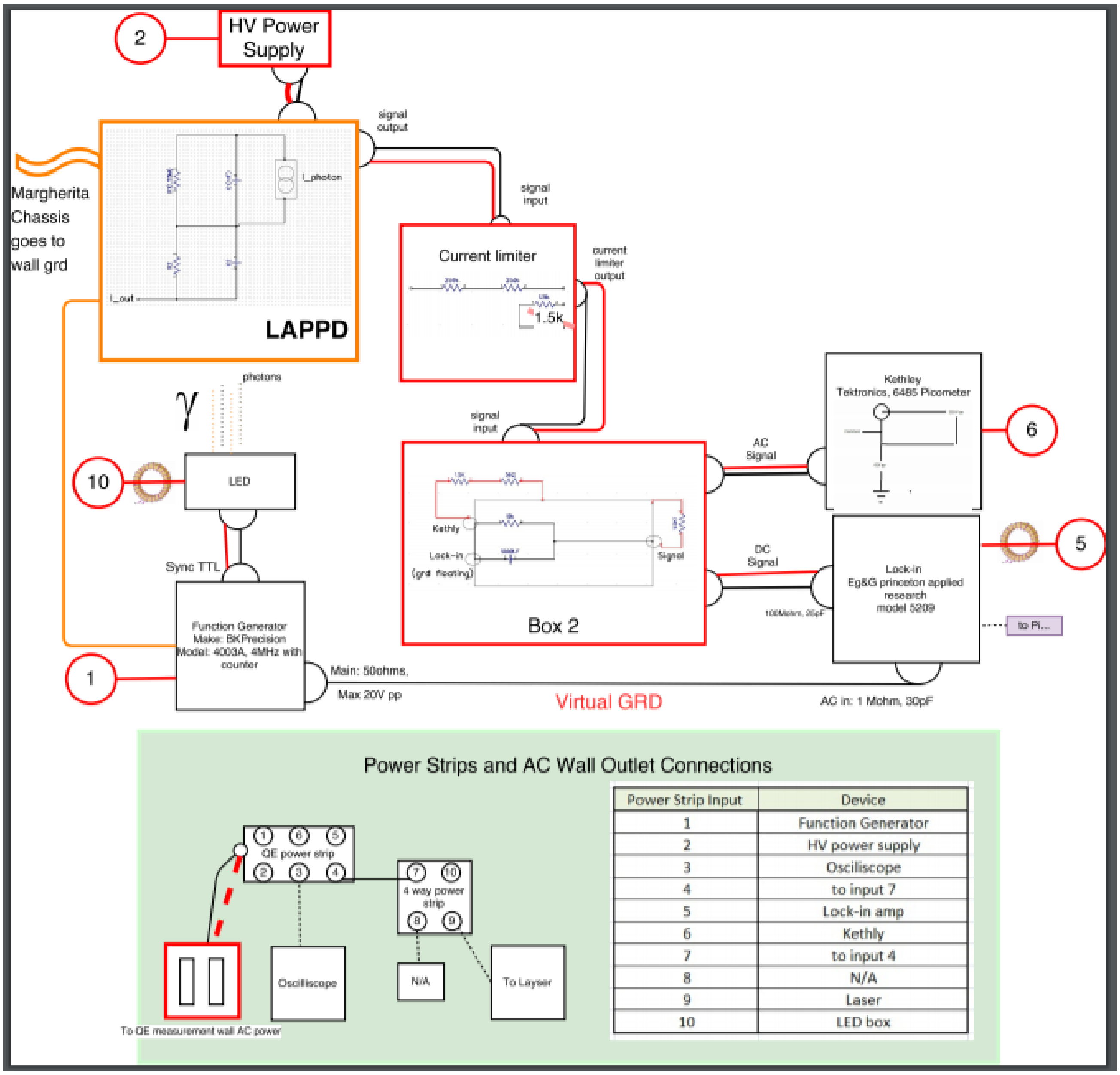
Depth	Depth Allowance	Height	Height Allowance	Width/ Length	Width/ Length Allowance
0.684	+ .007, -0	0.884	+ .007, -0	8.260	+.020, -.010

Table 4: Nominal values and allowances from the Spec Sheet in Appendix A.[3]

		Standard Deviation			Average				
Vendor	Base Number	Flatness of Depth	Flatness of Sealing Surface	Height	Depth	Sealing Surface	Height	Width/ Length	Notes
ICE	1	0.0008	0.0003	0.001	0.684	0.750	0.887	8.251/8.256	discolored
ICE	2	0.0007	0.0003	0.001	0.686	0.750	0.886	8.252/8.256	discolored
ICE	3	0.0005	0.0003	0.001	0.683	0.751	0.887	8.257/8.260	discolored
ICE	4	0.0005	0.0003	0.001	0.684	0.750	0.886	8.255/8.256	discolored
ICE	5	0.0007	0.0004	0.0008	0.683	0.751	0.882	8.255/8.251	discolored
Coorstek	1	0.0006	0.001	0.0008	0.675	0.751	0.886	8.267/8.267	rim inside
Aremco	2	0.001	0.0007	0.0006	0.685	0.751	0.885	8.262/8.261	gray spots
Aremco	3	0.001	0.0008	0.0004	0.684	0.751	0.884	8.257/8.256	gray spots
Aremco	4	0.001	0.0006	0.0003	0.683	0.751	0.884	8.256/8.259	gray spots

Table 5: Deviation form nominal values provided by the spec sheet[3]

C Current QE circuit diagram



Power Strip Input	Device
1	Function Generator
2	HV power supply
3	Oscilliscope
4	to input 7
5	Lock-in amp
6	Kethly
7	to input 4
8	N/A
9	Laser
10	LED box

Figure 10: The diagram of current QE setup.

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QC on Ceramic Tile Bases before Metalization

Quality control is used to evaluate the properties of LAPPD ceramic bases by making various precise measurements and tests. The measurements are used to determine which bases meet the specifications provided by the Spec Sheet in Figure 1 in assembly into the LAPPD and how to compensate for any inaccuracy in the bases that will be used.

Contents

1 Spec Sheet

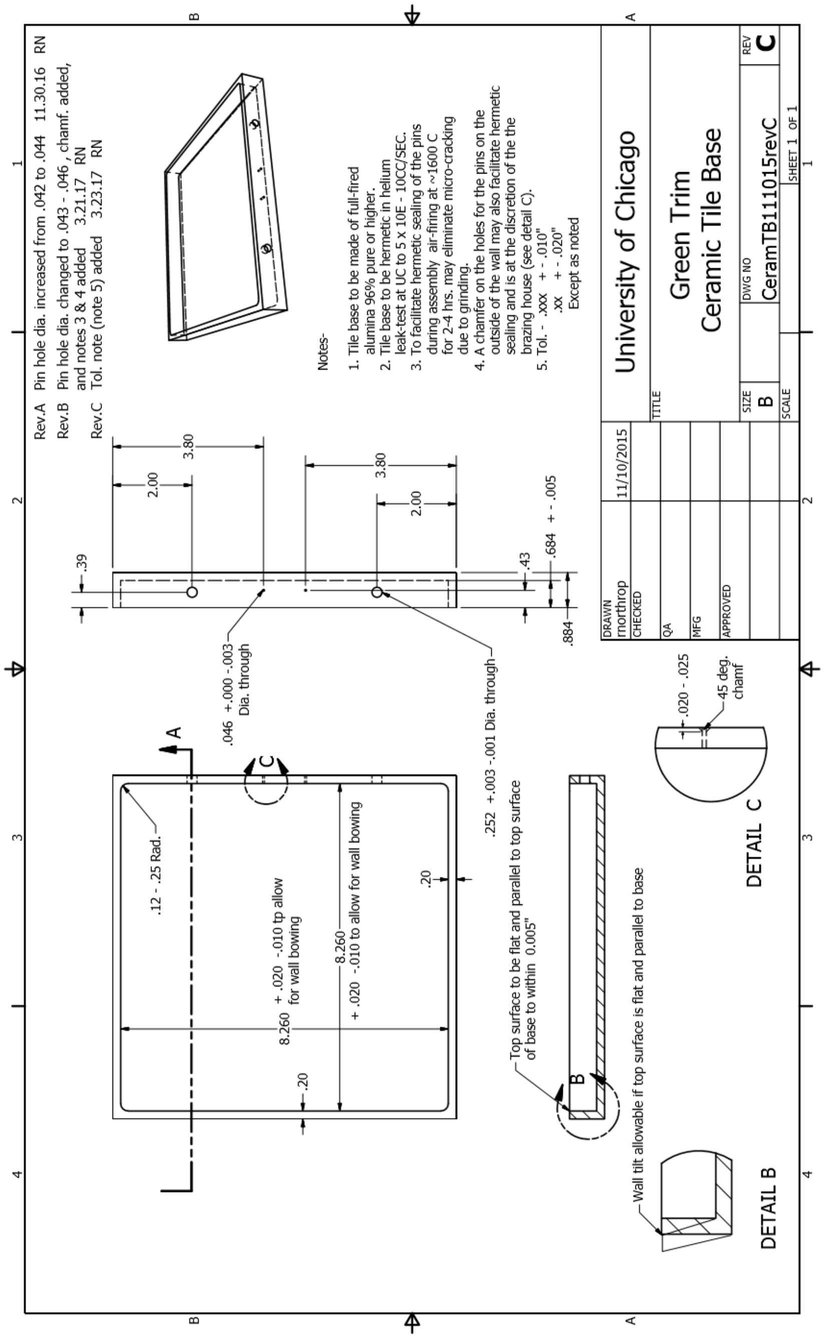

Figure 1: Specification sheet showing all desired dimensions of the ceramic base.

2 Height Measurement

Figure 2: Measurement of the height at 8 points of the ceramic base using a micrometer.

Equipment:

1. Ceramic Base
2. micrometer
3. gloves

Procedure:

1. Map of measurements is shown in Figure 3. This measurement only determines the height from the bottom of the ceramic base to the top face of the side walls (sealing surface).

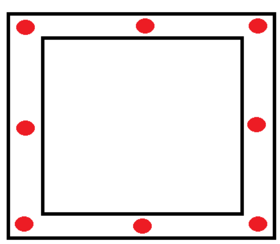

Figure 3: Map of height measurements. Red points represent the measurement points.

2. Place the micrometer at each point of the ceramic base. Turn the micrometer dial until it clicks. Try this multiple times to check that the measurement is consistent.
3. Read the Vermeer scale and record the measurement.
4. Nominal value should match the Spec Sheet in Figure 1. The uncertainty of micrometer measurements is about 0.1 mil.

3 Inside Depth Measurement

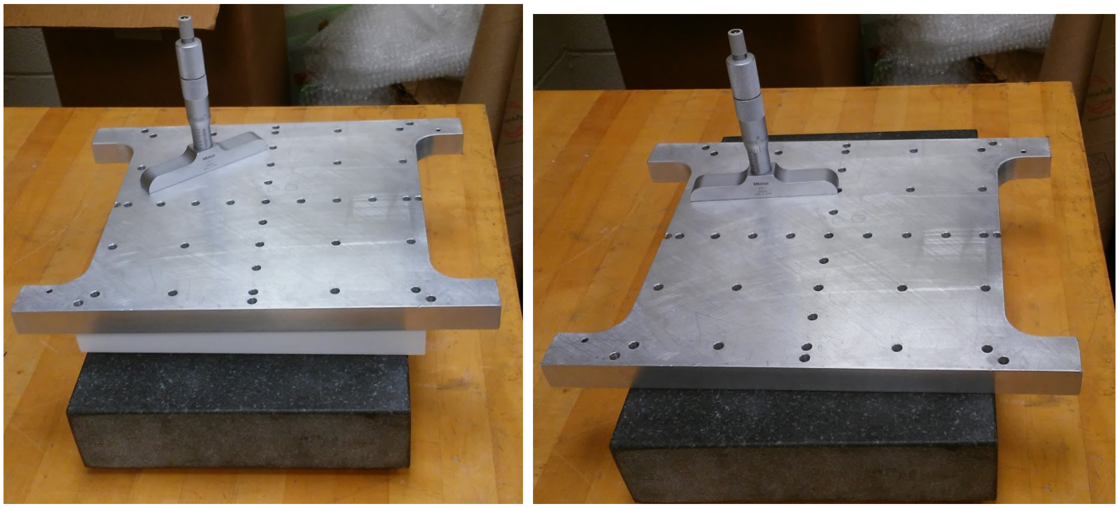

Figure 4: Measurements of the inside depth and top side of walls flatness. Left figure shows calibration of metal flat with drilled holes for measurement. Right figure shows the measurements with the ceramic base in between the granite flat and metal flat

Equipment:

1. Ceramic Base
2. granite flat
3. depth micrometer
4. flat metal plate with holes (calibrated)
5. gloves

Procedures:

- Calibration without Ceramic Base
  1. Measure the depth of each hole in the flat metal plate over the granite flat with the depth micrometer until it clicks.
  2. Read the value and record the data.
- Measurement with Ceramic Base
  1. Place the metal plate on the ceramic base, and using a depth micrometer, measure the depth from the top of the plate to the bottom of the base at 25 spots drilled in the metal flat.
  2. Make sure that the depth micrometer is placed in the same orientation at each measurement to keep the results reproducible. Also make sure to hold down the micrometer so that it is touching the surface entirely.
  3. Remeasure a few points to check for consistency of the results.
  4. Read and record the values.

5. Subtract the measured depth of each hole in the metal plate from the corresponding measurements of depth of the bases, to account for depth added by the metal plate. The final depth d is calculated using the following equation:

$$d = d_{mb} - d_m + 1$$

where d is the final inside depth, d_{mb} is the measured depth of the metal flat over the base plate, d_m is the measured depth of just the metal plate an 1 is the value that accounts for the bar size used in the depth micrometer.

6. The measurement uncertainty is about 0.1 mil and the measurement should correspond to the Spec Sheet in Figure 1.

4 Outside Depth Measurement

Equipment:

1. Ceramic Base
2. granite flat
3. depth micrometer
4. flat metal plate with holes (calibrated)
5. gloves

Procedures:

1. Calibrate the metal flat using the same procedure as calibration in Inside Depth Measurement (Section 2).
2. Place the metal plate on the ceramic base, and using a depth micrometer, measure the depth from the top of the plate to the top of the top of the edges of the base at 8 points (as shown in Figure 3) along the edges of the base.
3. Subtract the measured depth of each hole in the metal plate from the corresponding measurements of outside depth of the bases, to account for depth added by the metal plate.
4. The uncertainty of the measurements was approximately 0.1 mil.
5. This measurement allows to determine the variance between each individual point measured and so the flatness of the sealing surface.

5 Width and Length Measurements

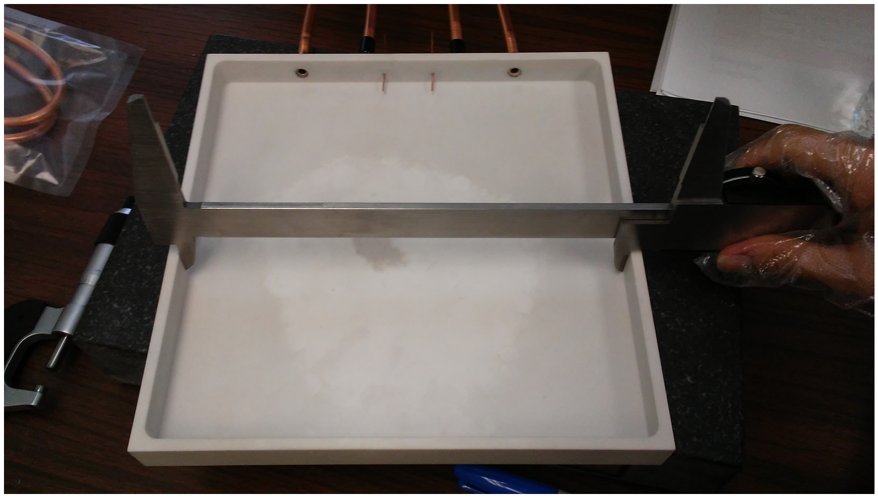

Figure 5: The width and height measured with a caliper

Equipment:

1. Ceramic Base
2. caliper
3. gloves

Procedures:

1. Line-up the caliper on the inside of the base walls, making sure the caliper is straight.
2. Tighten the safety screw when the caliper is set at the right distance.
3. Pull out the caliper and record the measurement.
4. Repeat this procedure for both the inside width and length.

6 Errors to avoid

1. Wear gloves and keep the area clean.
2. Do not touch the ceramic with skin, the oil sticks to the ceramic even after baking.
3. Be careful and avoid scratching of the ceramic.
4. Make sure you read the scales on the micrometers accurately and try to reproduce the results.

7 Database

Link to the database of current Ceramic Base QC measurements: http://ceramicbases.uchicago.edu/
Link to the directory of the script for the Database:/psec/site/static/ceramicbases.uchicago.edu

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Assembling and Testing TTL to Differential Circuits for Differential Signaling

This report describes two circuits and connections required to implement differential signaling. The first circuit is a Driver in Figure 1 that converts TTL signal to Differential and the second circuit is a Receiver in Figure 2 that convert Differential signal back to TTL. Further, the report contains procedures on testing an assembled circuit and its nominal results.

Contents

1 TTL to Differential Driver Circuit Diagram

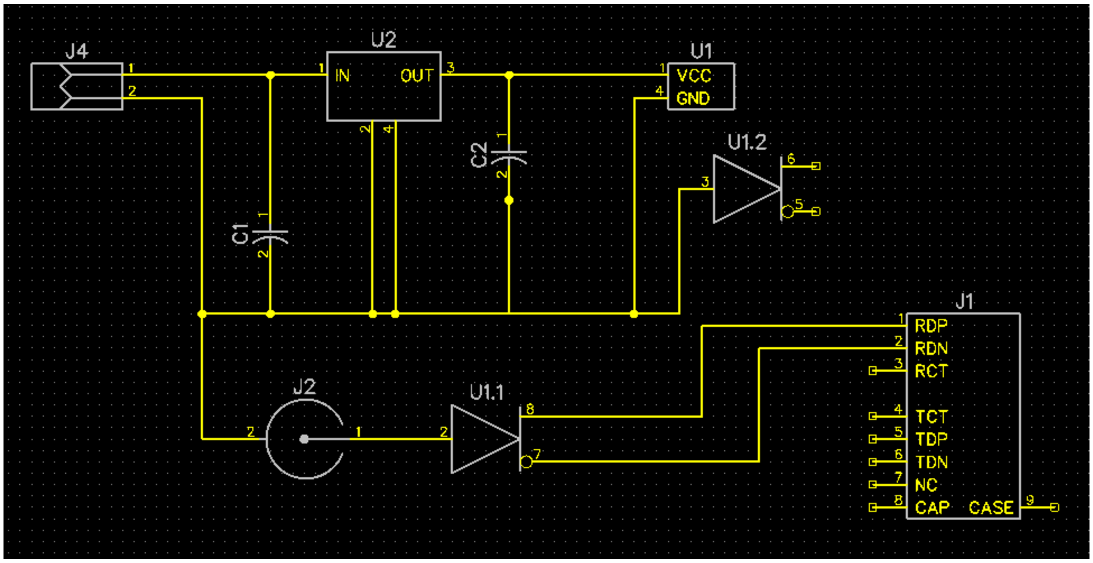

Figure 1: Circuit diagram for a driver that converts signal from TTL to differential. The components are: J1=Ethernet connector for differential output to circuit in Figure 2, J4=power connector, J2=BNC TTL input connector from function generator, U2= voltage regulator to 5V (LM2937ES), C1 = 0.1μF capacitor, C2 = 10μF capacitor, U1 + U1.1 + U1.2 are all part of the DS9638CM driver chip that converts from TTL to Differential.

2 Differential to TTL Receiver Circuit Diagram

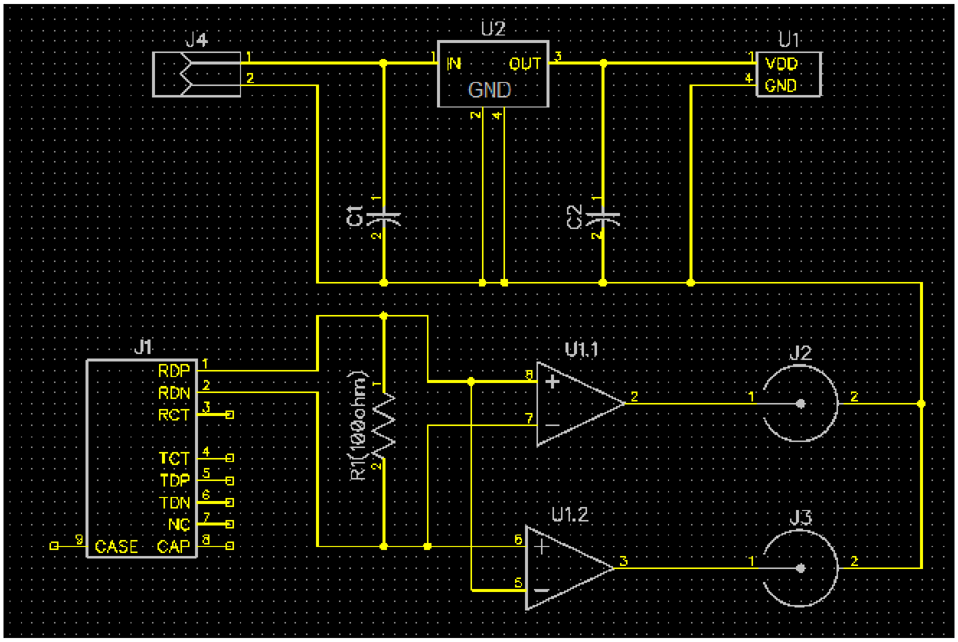

Figure 2: Circuit diagram for a receiver that converts signal from differential to TTL. The components are: J1=Ethernet connector for differential input from circuit in Figure 1, J4=power connector, J2=BNC TTL output connector to LED box (at phase), J3=BNC TTL output connector to LED box (out of phase), U2= voltage regulator to 5V (LM2937ES), C1 = 0.1μF capacitor, C2 = 10μF capacitor, R1= 100Ω resistor, U1 + U1.1 + U1.2 are all part of the DS9637ACN receiver chip that converts from Differential to TTL.

3 Testing Procedures

3.1 Equipment

Number	Equipment	Company/Model	Description
1	Driver Circuit	N/A	Figure 1
2	Receiver Circuit	N/A	Figure 2
3	Power Supply	N/A	above 5V
4	LED Box	Prizmatix	wavelengths = 365nm,405nm,500nm,535nm
5	Function generator	BK Precision 4003A	4MHz function generator with counter, set to 350Hz (current setting at Margherita 1), set to 10Hz scale to see LED flashing
6	Oscilloscope	RIGOL DS2202A	set to 1MΩ impedance at channel input option for appropriate signal amplitude (will have impedance mismatch)
7	3 BNC cables	N/A	BNC from Function Generator to T splitter on Oscilloscope input for reference, BNC from T splitter on Oscilloscope to input on Driver circuit, BNC from output of Receiver to second Oscilloscope input or LED box TTL input
8	T splitter	N/A	at input of Oscilloscope, splitter for TTL signal to Oscilloscope and the circuit
9	Ethernet cable	N/A	connects Driver Differential output and Receiver Differential input
10	wires	N/A	Connect power supply to both Driver and Receiver
11	multimeter	N/A	N/A

3.2 Procedures

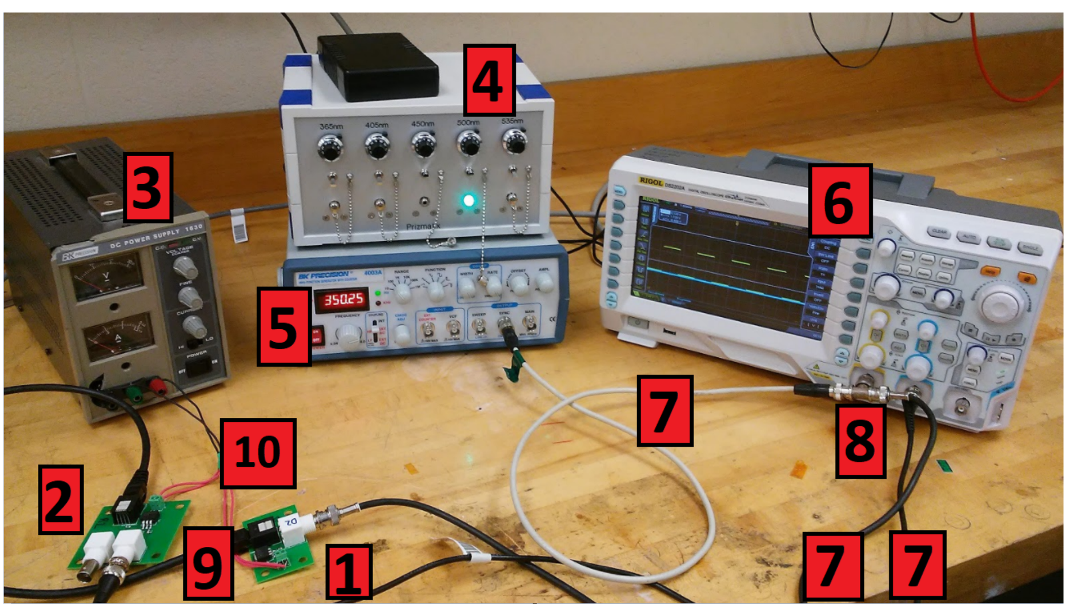

Figure 3: Image of the Test set-up for the Driver and Receiver circuits

3.2.1 Set-up procedure

1. Use the multimeter to check witch input on the power connector (component J4) on both Driver and Receiver is positive and ground. Use the wires to connect power supply positive output to the Driver and Receiver circuit power connectors. Use the wires to connect power supply ground output to the Driver and Receiver circuit power connectors. Short the negative output on the power supply to ground.

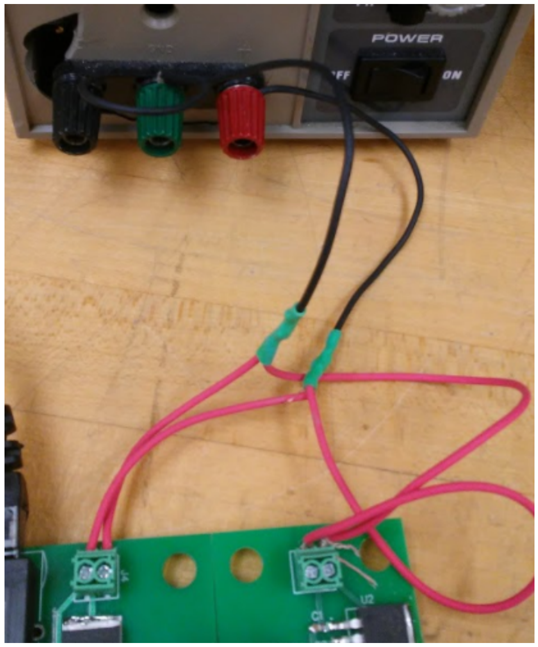

Figure 4: Connections to power.

2. Plug in the Ethernet cable to the Ethernet connectors (component J1) one end to the Driver circuit and the other end to the Receiver circuit.

3. Connect the first BNC cable to the SYNC Output on the function generator to the T connector.

4. Connect T connector to the CH1 input on the oscilloscope.

5. Connect a second BNC cable to the T connector plugged into the oscilloscope. Connect the same BNC cable to the Driver BNC connector (component J2).

6. Connect the third BNC cable to the BNC connector on the Receiver circuit (component J2 for in-phase results or component J3 for out-of-phase results). Connect the other end of the BNC cable to the CH2 input on the oscilloscope for view of the signal or the LED TTL input to see the LED flash.

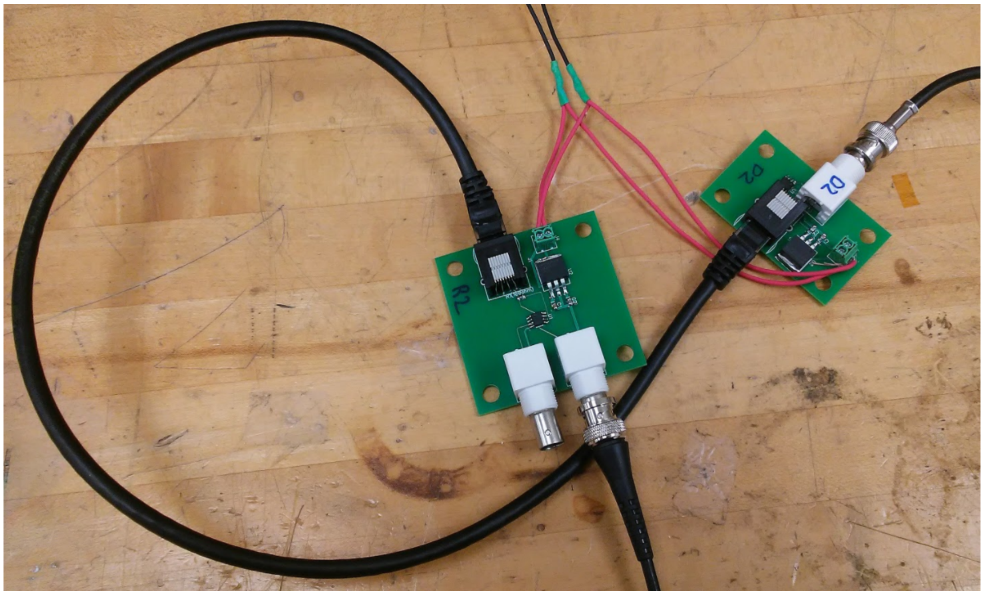

Figure 5: Connections between the Driver and Receiver circuits.

Figure 6: Connections at the back of the LED Box.

Figure 7: Connections at the Function Generator on the left and Oscilloscope on the right.

3.2.2 Testing Settings Before turning on the power

1. Function Generator

   - Plug-in Function Generator
   - Set the function generator to 350Hz to test the circuits under the same frequency as the Margherita 1 setup.
   - Set the function generator to some range of 10Hz to watch LED flashes.

2. Oscilloscope

   - Plug-in the Oscilloscope
   - Set the oscilloscope impedance to 1MΩ at the CH1 input option and Ch2 input option to see the 5V output of the reference signal and the proper output of the circuit signal.
   - Set the oscilloscope impedance to 50Ω at the CH1 input option and Ch2 input option to see the signal and regulate the amplitude using the CMOS ADJ option on the function generator. This option will result in a lower amplitude of the circuit signal.
   - Set both channels to DC coupling.
   - Recommended amplitude setting: 2V for 1MΩ impedance.

3. LED Box

   - Plug in the Box
   - Flip the power switch on in the back of the box
   - Flip the LED switch on in the front and back of the box at desired wavelength to see the LED light. Flip the switch off in the back of the box to use the TTL signal and see flashes.

3.2.3 Testing Procedure

1. Turn on the power supply to operate at 5V.

2. Use the oscilloscope to determine the reference signal from the function generator

3. When the circuit signal is plugged into the oscilloscope, check the signal amplitude and phase, check impedance mismatch, check for any spikes, ripples, noise in waveform, touch/move around some components in the setup to see if the waveform stays consistent.

4. When the circuit is plugged into the LED, check if the LED is flashing and if it stays operational.

5. During all testing, check if the Driver and Receiver chips are overheating

3.3 Nominal Results and Potential Bad Results

1. When circuit signal is plugged into the oscilloscope

   - The circuit signal should be between 4V and 5V in amplitude
   - There should be minimum noise, ripples, spiking of the waveform.
   - Some noise might not interfere with the signal frequency to the LED box.

- The waveform should be steady.
- If there is jumping of the waveform or too much noise, if the signal looks weird when the components are touched there might be a soldering issue.

2. When circuit signal is plugged into the LED Box

   - The plugged in LED should flash at the set frequency of the function generator.
   - Phase should match the output plugged into the circuit.

3. Chips on the circuit might get warm but should not get extremely hot.

Figure 8: Top: In-phase oscilloscope display of signal. Bottom: Out-of-phase oscilloscope display of signal. Yellow: display of the reference TTL signal from function generator. Blue: display of the TTL signal from the Differential circuit. The Blue has a slightly lower amplitude after passing through the circuit at ≈ 4V

4 Application of Differential Signaling

This circuit is meant to be used between the function generator and the LED BOX in the QE set-up of Margherita 1 and 2 to reduce noise when measuring QE. Ferrite Beads may be placed on the Ethernet cable connecting the Driver and Receiver circuit to further reduce signal interference.